CA2 ON
EV . 506
R44
c.2

c.2

PHYTOPLANKTON STUDIES IN THE BAY OF QUINTE

I-physical, chemical and phytoplankton characteristics

research report w44

1973

LEGISLATIVE LIBRARY OF ONTARIO
TORONTO
OCT 5 1973
RECEIVED

Ministry of the Environment
Ontario

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact ServiceOntario Publications at copyright@ontario.ca

CA2 ON
EV. 506
R44
C. 2

Ontario

PHYTOPLANKTON STUDIES IN THE BAY OF QUINTE:

I - PHYSICAL, CHEMICAL AND PHYTOPLANKTON CHARACTERISTICS

by

A.E. Christie, Ph.D

July, 1973

Research Report W44

Research Branch

Ministry of the Environment
135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

ABSTRACT

Phytoplankton-nutrient relationships in the trophogenic waters of three major zones of the Bay of Quinte, an arm of Lake Ontario, were examined during the ice free periods of 1967, 1968.

Maximum standing crops of algae in each zone, which consisted mainly of Bacillariophyta and Cyanophyta, were 91, 37, and 20 $cm^3.m^{-3}$ at Big Bay, Glenora, and Conway. Direct relationships between algal quantities and nitrogen and phosphorus concentrations were evident in at least two regions. During the spring of 1968, algal responses were found significantly related to changes in dissolved silicate levels. Relationships between inorganic carbon availability and phytoplankton development were also examined.

From maximum ratios between phosphorus and nitrogen concentrations and associated algal quantities, phytoplankton levels in excess of 10 $cm^3.m^{-3}$ may be anticipated when total phosphorus and total nitrogen levels are allowed to exceed and remain in excess of 0.01 $g.m^{-3}$, and 0.13 $g.m^{-3}$ respectively, if no other factor is exerting a limiting influence on growth.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Nutritional enrichment of Ontario surface waters by natural or cultural processes has resulted in excessive growths of algae, particularly phytoplankton, with a concomitant deterioration of water quality in some locations to the point where water treatment plants are almost continuously beset with taste and odour and/or filter clogging problems and recreational activities are severely repressed.

Guidelines for nutrient discharge control practices to prevent future deterioration and promote recovery in surface waters are required. In situ studies of phytoplankton growths and aqueous fertility were initiated in 1967. A relationship between inorganic carbon availability, as measured by alkalinity, and phytoplankton development observed by Birge and Juday (1922) was also noted during simultaneous examination of several southern Ontario lakes (Christie, 1968). Investigations in the Bay of Quinte by Tucker (1948) and McCombie (1967) suggest the existence of a gradient in phytoplankton development where inorganic carbon availability, alkalinity about 100 $g.m^{-3}$ as $CaCO_3$, would not be expected to exert a limiting nutritional influence on phytoplankton responses.

Examination of nutrient phytoplankton relationships with particular emphasis on the roles of phosphorus

and nitrogen in biomass responses was therefore carried out during 1967 and 1968 in the Bay of Quinte. Physical, chemical and phytoplankton characteristics of the region are presented below. Phytoplankton responses as related to seston nutrient content, and the results of various productivity studies will be described in subsequent reports.

STUDY AREA

The Bay of Quinte is a narrow Z-shaped body of water located on the northeastern shore of Lake Ontario (Figure 1). The bay, which almost separates Prince Edward County from the mainland, is about 96 km in length and consists of three major regions (McCombie, 1967).

The innermost region stretches for a distance of 48 km from Trenton to Deseronto and is connected at the western end, for navigational purposes, to Lake Ontario by the Murray Canal. Depths in this region range from 4 - 8 m. Beyond Belleville the bay widens to form a rectangular area known as Big Bay, approximately 6.5 km by 3 km. The middle region of the Bay of Quinte, Long Reach, lies southwesterly for 16 km from Deseronto to Glenora and deepens from 6 - 18 m. Just above Glenora the bay extends to the northeast to form Hay Bay and Picton Bay on the western side. Adolphus Reach, the third region of the Z, stretches 20 km from Glenora to Pleasant Point

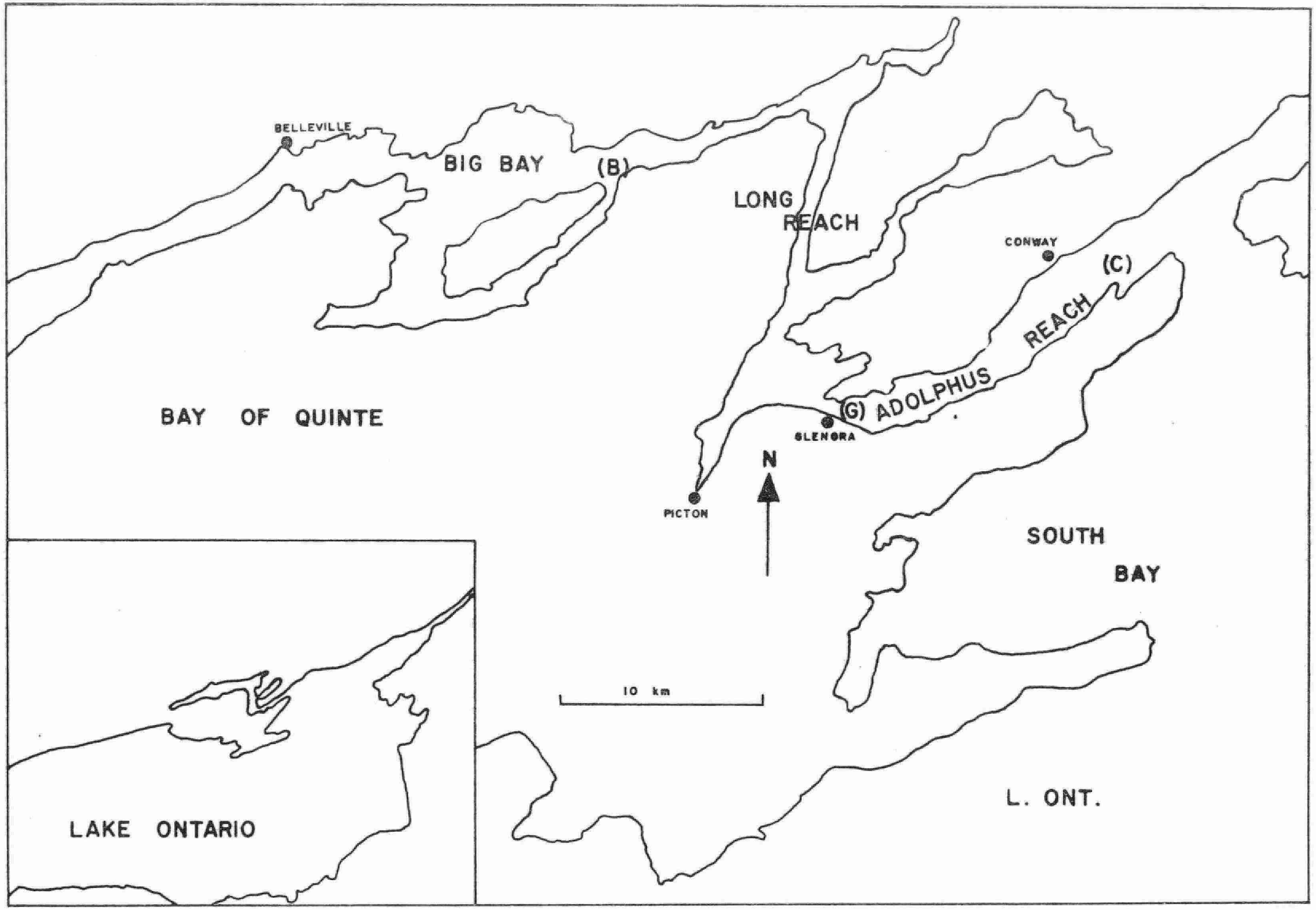


Figure 1. A partial map of the Bay of Quinte plus insert of Lake Ontario. Locations of sampling stations are indicated for Big Bay (B), offshore from Glenora (G), and near Conway (C).

and increases in depth to about 55 m just off Prinyer Cove at the tip of Pleasant Point. Entry to Lake Ontario occurs via two channels around Amherst Island.

Steep cliffs of Ordovician limestone extend along the south side of Adolphus Reach, both sides of Long Reach and occur also at Picton Bay. Except for some areas of steep banks along the north shore of Adolphus Reach the remaining shoreline throughout the Bay is gently sloping (Chapman and Putnam, 1962).

Major rivers enter the bay along the north shore of the inner region and include the Trent, Moira, Salmon and Napanee. Numerous small creeks are evident elsewhere along the shores around the bay. The larger rivers originate in the Precambrian Shield and subsequently traverse areas of glacial till and limestone plains. Agriculture in the immediate vicinity of the bay ranges from mixed farming to canning crops and fruit orchards.

METHODS AND MATERIALS

Sampling of the trophogenic waters of the Bay of Quinte was carried out by passing a narrow mouth 1.1 litre (40 ounce) bottle, mounted in a weighted container, through a column of water to the depth of the one percent isophot at bi-weekly intervals from April to October, 1967, 1968.

Samples for chemical and chlorophyll analyses were stored in a dark, cool location until forwarded to

the main laboratory at Toronto, normally within one day of sampling. If a longer delay was anticipated, samples for chlorophyll analyses, either a 1000 ml or 500 ml volume, received a 1 ml aliquot of saturated $MgCO_3$ solution and were filtered through a 47 mm 1.2 micron membrane. After filtration the membrane was placed upon an absorptive pad contained in a plastic petri dish and stored in a refrigerator. Chemical and chlorophyll analyses of samples were carried out following procedures described in Standard Methods (1965) or as subsequently outlined by Brydges (1970).

One litre samples of raw water for phytoplankton enumeration were treated, in 1967, with 35 ml of 0.7 $g.l^{-1}$ HgCl (Johnson et al, 1970), and in 1968 with 20 drops of Lugol's solution. Phytoplankton samples in 1967 were concentrated using a Sedgwick-Rafter sand filter funnel plus two layers of bolting silk (Johnson et al, 1970). Final volume of concentrate was 25 ml. In 1968 a sedimentation technique using Lugol's solution was employed. This was a two-step process in which a 1 litre sample of water was placed in a 1 litre graduate cylinder, covered and allowed to stand for one week. After removal of the supernatant by siphoning, the remaining 25 ml of concentrate plus at least two 25 ml rinses of distilled water were accumulated in a 100 ml graduate, treated again

with Lugol's solution, covered and allowed to stand for another week. The volume was again reduced by siphoning to 10 ml, and this concentrate plus three 5 ml rinses of distilled water was then retained in a 28 ml (one ounce) vial until examined. Filtration of supernatants from the sedimentation technique through a 47 mm 0.45 micron membrane indicated no loss of algae during these stages of the concentration procedure. Enumeration of the phytoplankton, which was based on examination of between 150 - 200 organisms, was carried out using a Sedgwick-Rafter cell under a magnification of 200 X with the results being expressed as parts per million by volume (cm^3) or Areal Standard Units (ASU). One Areal Standard Unit is equivalent to a cross-sectional area of 400 square microns. Various texts were employed to aid in identification of the phytoplankton (Prescott, 1951; Sieminska, 1964; Frere Irene-Marie, 1938; Smith, 1950).

The depth of trophogenic zone - the location of the one percent isophot - was normally estimated by doubling the average depth at which a secchi disc disappeared and reappeared. Preliminary comparisons early in the programme indicated that doubling the secchi disc reading approximated the depth of the one percent isophot as established using a submarine photometer at the three sampling stations. The reliability of this relationship

was recalibrated at each sampling location in June, August, September, 1967 and June, 1968. A comparison of the results obtained by the two techniques when analyzed statistically showed no significant difference between the two methods of establishing the depth of the one percent isophot - mean of twice secchi disc 4.2 metres; mean from photometer - 4.2 metres, F exp. = 0.00.

Stratified sampling of the trophogenic column at a minimum of five depths was carried out in June, August, October, 1967 and June, 1968 at the three sampling locations. Average values of several parameters for each column when compared to values of the same parameter obtained from passage of a single bottle indicated no significant difference to exist between the values obtained by either method (Table I).

Statistical analyses of data accumulated in this study were carried out using techniques described in Snedecor and Cochran (1957).

RESULTS

PHYTOPLANKTON

Standing Crops

Seasonal variations in the total standing crops of phytoplankton present in the trophogenic waters at each sampling station - Big Bay (B), Glenora (G), Conway (C), during 1967 and 1968 are illustrated as parts per million

TABLE I

Comparisons between the results of composite (C) and the average of stratified (S) sampling of the trophogenic waters of the Bay of Quinte.

Parameter		C	S	F exp.
mean total phosphorus	$g.m^{-3}$	0.051	0.052	0.01
mean total nitrogen	$g.m^{-3}$	0.77	0.67	0.87
mean alkalinity (as $CaCO_3$)	$g.m^{-3}$	99	99	0.03
mean total dissolved solids	$g.m^{-3}$	170	177	0.28
mean algae	$10^{12} ASU.m^{-3}$	1.09	1.95	0.09

by volume (cm^3), Areal Standard Units (ASU), and concentrations of chlorophyll a (mg), per unit volume (m^{-3}) (Figure 2). Chlorophyll data for certain samples were unavailable in 1968.

The above data have been summarized in Table II with respect to the mean and maximum quantities of phytoplankton biomass at each station.

Various comparisons with respect to standing crops of phytoplankton were carried out and the significance of differences between means tested at the $F_{.05}$ level. The results of these analyses, listed in Table III, indicate that biomass quantities over the two year period in Big Bay (BT) were significantly greater than at Glenora (GT) and Conway (CT) with respect to $cm^3.m^{-3}$ and $ASU.m^{-3}$, Glenora and Conway being equivalent. All locations were found dissimilar on the basis of chlorophyll a ($mg.m^{-3}$). No differences ($cm^3.m^{-3}$) were found between the same station in different years, or between years for the entire Bay of Quinte (Quinte 7 = Quinte 8), but are apparent ($ASU.m^{-3}$) between Big Bay in 1967 (B7) and Big Bay in 1968 (B8), though not with G7 versus G8, C7 versus C8, or for the entire Bay of Quinte (Quinte 7 versus Quinte 8).

Composition

Seasonal variation in the percentage composition of the phytoplankton communities at each station is

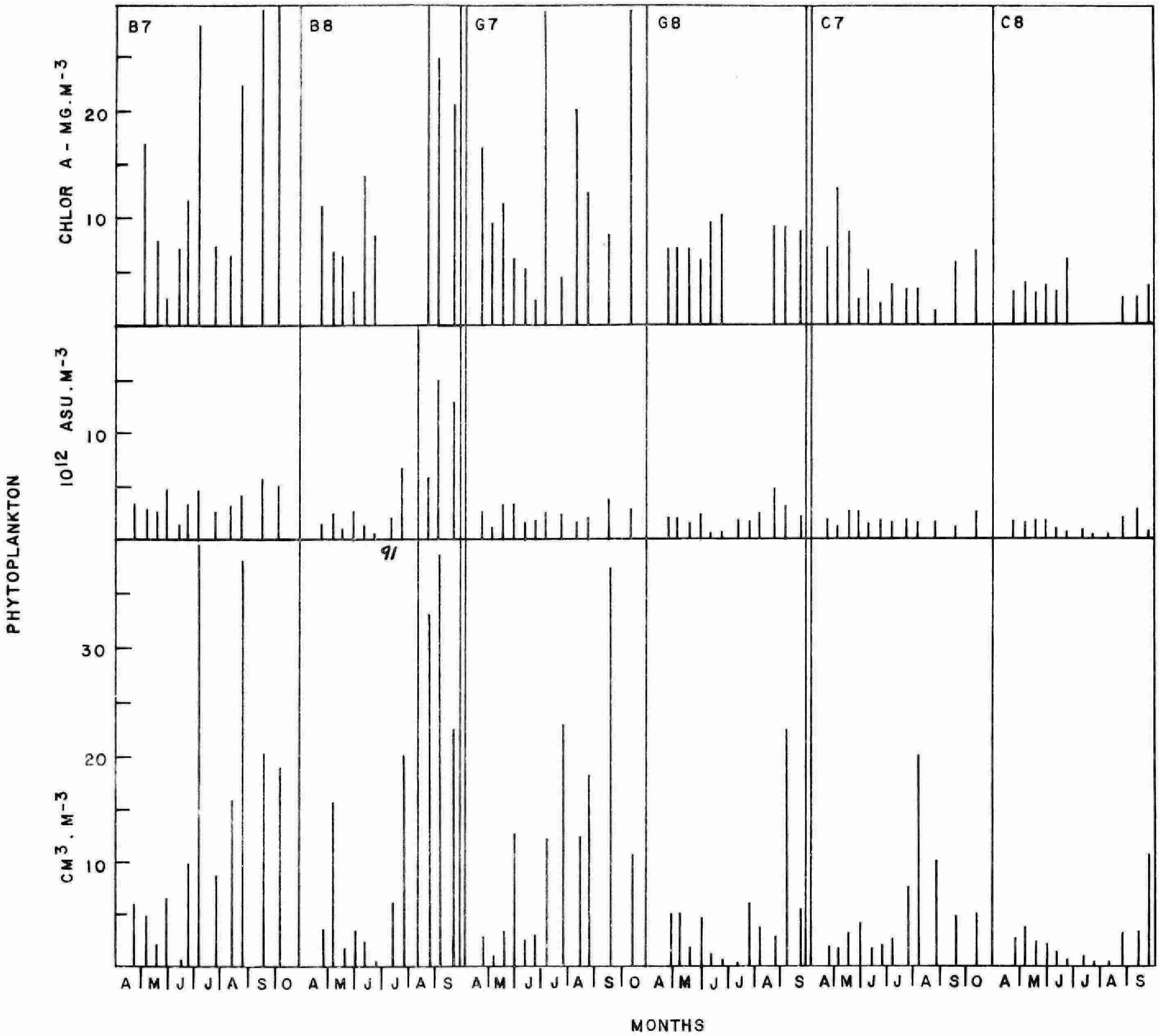


Figure 2. Seasonal variations in the standing crops of phytoplankton ($cm^3.m^{-3}$, 10^{12} $ASU.m^{-3}$) and chlorophyll a ($mg.m^{-3}$) at Big Bay (B), Glenora (G) and Conway (C) during 1967, 1968.

TABLE II

Average and maximum concentrations of phytoplankton and chlorophyll a during 1967 and 1968.

Location	$cm^3.m^{-3}$			10^{12} $ASU.m^{-3}$			chlor. a $mg.m^{-3}$		
	mean	max.	obs.	mean	max.	obs.	mean	max.	obs.
1967									
Big Bay	14.42	40.72	12	3.29	6.03	12	16.8	45.2	11
Glenora	11.53	37.43	12	2.27	3.44	12	12.8	30.6	12
Conway	5.34	20.25	12	1.59	2.34	12	5.1	12.8	12
1968									
Big Bay	19.94	91.00	12	8.63	51.62	12	16.6	51.5	9
Glenora	4.88	22.49	12	1.98	3.15	12	8.1	10.2	9
Conway	2.34	10.73	12	1.03	2.54	12	3.6	6.0	9

TABLE III

Comparisons with respect to phytoplankton development ($cm^3.m^{-3}$, 10^{12} $ASU.m^{-3}$, $mg.m^{-3}$ chlor. a) throughout the Bay of Quinte, 1967, 1968. Differences significant at $F_{.05}$ level.

algae		chlor. a
$cm^3.m^{-3}$	10^{12} $ASU.m^{-3}$	$mg.m^{-3}$
BT $>$ GT = CT	BT $>$ GT = CT	BT $>$ GT = CT
B7 = B8; G7 = G8; C7 = C8	B7 $<$ B8; G7 = G8; C7 = C8	
B7 = G7 = C7	B7 = G7 = C7	
B8 $>$ G8 = C8	B8 $>$ G8 = C8	
Quinte 7 = Quinte 8	Quinte 7 = Quinte 8	

portrayed on the basis of $cm^3.m^{-3}$ and $ASU.m^{-3}$ (Figure 3). Following the loss of ice cover in April the populations at each station were dominated by the Bacillariophyta. By July the Cyanophyta became more evident, particularly in Big Bay and at Glenora. At Conway in midsummer increasing concentrations of bluegreens occurred but the community at times also contained a fairly good representation of other algal forms, the Chlorophyta and Pyrrophyta being most noticeable.

The average percent composition of the phytoplankton communities, on the basis of $cm^{-3}.m^{-3}$ and $ASU.m^{-3}$ is listed in Table IV. The Cyanophyta and Bacillariophyta comprise the major components of the community in the Bay of Quinte. The relative proportions of the population at each location between these two groups vary somewhat depending on the method of enumeration.

The various phytoplankton forms observed during the study are listed in Table V. Speciation was limited to samples obtained in June, August, October, 1967 and June, August, September, 1968.

Phytoplankton Unit Comparison

Relationships between the various methods of expressing the phytoplankton biomass were examined (Table VI). Highly significant linear relationships were obtained in every case but one - ASU versus cm^3.

Figure 3. Seasonal variations in the composition of the standing crops of phytoplankton at Big Bay (B), Glenora (G) and Conway (C) during 1967, 1968, based on $cm^3.m^{-3}$ and 10^{12} $ASU.m^{-3}$.

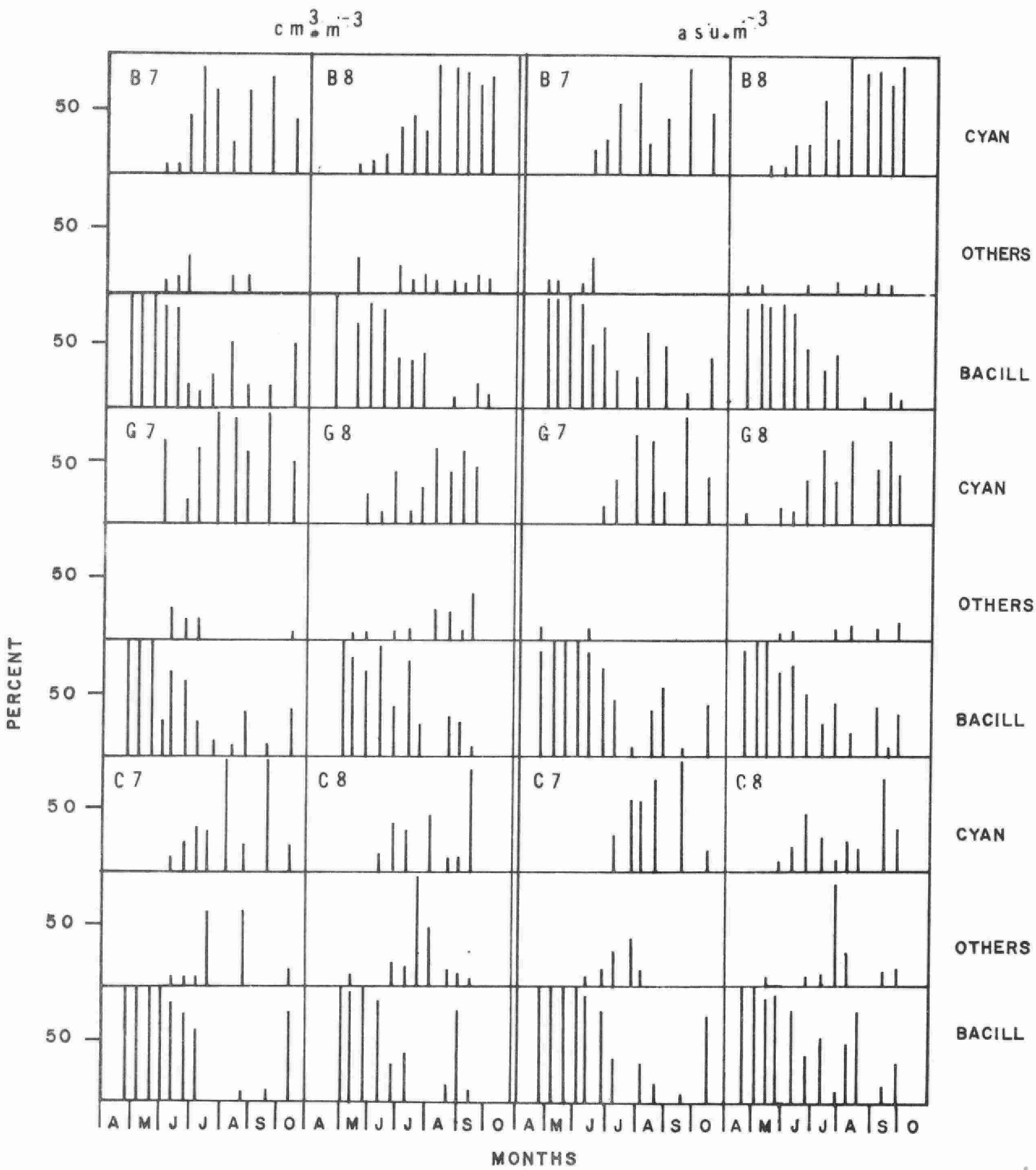


TABLE IV

Average percent composition of the phytoplankton standing crop, 1967, 1968 based on $cm^3.m^{-3}$ and $ASU.m^{-3}$.

	Bacillariophyta	Cyanophyta	Others
cm^3			
Big Bay	22.5	70.2	7.3
Glenora	30.5	63.6	5.9
Conway	38.1	47.0	14.9
ASU			
Big Bay	25.7	64.8	5.0
Glenora	57.3	36.9	5.8
Conway	69.0	24.1	6.9

TABLE V

Algal flora of the Bay of Quinte

Cyanophyta

Aphanizomenon flos-aquae	Rolfs
Aphanocapsa species	Naegeli
Anabaena circinalis	Rabenhorst
Anabaena species	Bory
Chroococcus dispersus	(Keissl) Lemmermann
Chroococcus limneticus	Lemmermann
Coelasphaerium pallidum	Lemmermann
Gomphosphaeria aponina	Kuetzing
Gomphosphaeria lacustris	Chodat
Lyngbya Birgei	Smith, G.M.
Lyngbya species	Agardh
Merismopedia punctata	Meyen
Microcystis aeruginosa	Kuetzing
Microchaete Goeppertiana	Kirchner
Oscillatoria princeps	Vaucher
Oscillatoria species	Vaucher
Nostoc species	Vaucher

Chlorophyta

Arthrodesmus triangularis	Lagerheim
Arthrodesmus species	Ehrenberg
Ankistrodesmus falcatus	(Corda) Rolfs
Ankistrodesmus fractus	(West & West) Brunnthaler
Oedogonium species	Link
Scenedesmus incrassatulus	Bohlin
Scenedesmus obliquus	(Turpin) Kuetzing
Scenedesmus opliensis	Richter, P.
Scenedesmus species	Meyen
Sdenastrum gracile	Reinsch

cont....

Staurastrum cuspidatum	Brebisson
Staurastrum anatiuum	Cook & Wills
Staurastrum (Johnsonii) despauperatum	Smith, G.M.
Staurastrum inflexam	Brebisson
Staurastrum megacanthum	Lund
Staurastrum paradoxam	Meyen
Staurastrum Sebaldi	Reinsch
Staurastrum species	Meyen
Staurastrum natator	West
Staurastrum hexacerum	(Ehr.) Brebisson
Tetraedron limneticum	Borge
Tetraedron lunula	(Reinsch) Wille
Tetraedron lobulatum	(Naegeli) Hansgirg
Tetraedron minimum	(A. Braun) Hansgirg
Tetraedron muticum	(A. Braun) Hansgirg
Tetraedron regulare	Kuetzing
Tetraedron trigonum	(Naegeli) Hansgirg
Tetraedron species	Kuetzing
Treubaria setigerum	(Archer) Smith, G.M.
Schroederia Judayi	Smith, G.M.
Sphaerocystis Schroeteri	Chodat
Coelastrum sphaerixum	Naegeli
Actinastrum Hantzschii	Tagerheim
Coelastrum microporum	Naegeli
Coelastrum reticulatum	(Dang.) Senn
Coelastrum species	Naegeli
Botryococcus protuberans	Smith, G.M.
Crucigenia quadrata	Morren
Dictyosphaerium Ehrenbergianum	Naegeli
Dictyosphaerium pulchellum	Wood
Cosmarium quinarium	Lund
Cosmarium species	Corda
Golenkinia radiata	Wille (Chodat)
Lagerheimia ciliata	(Lagerheim) Chodat

cont....

Oocystis solitaria	Wittrock
Oocystis borgei	Snow
Oocystis elliptica	West, W.
Pediastrum boryanum	(Turpin) Meneghini
Pediastrum duplex	Meyen
Pediastrum simplex	(Meyen) Lemmermann
Pediastrum obtusum	Lucks
Pediastrum tetras	(Ehrenberg) Ralfs
Scenedesmus bijuga	(Turpin) Lagerheim
Scenedesmus acuminatus	(Lagerheim) Chodat
Scenedesmus dimorphus	(Turpin) Kuetzing
Scenedesmus denticulatus	Lagerheim
Scenedesmus Bernardii	Smith, G.M.
Scenedesmus armatus	(Chodat) Smith, G.M.
Scenedesmus quadricauda	(Turpin) Brebisson
Coelastrum cambricum	Archer
Chlorococcum humicola	(Naeg.) Rabenhorst
Characium limneticum	Lemmermann
Spirogyra species	Link
Mougeotia species	(C.S. Agardh) Whittrock
Planktosphaeria gelatinosa	Smith, G.M.
Westella linearis	Smith, G.M.
Ulothrix species	Kuetzing
Spirogyra Collinsii (zygospore)	(Lewis) Printz
Oocystis crassa	Wittrock
Closterium species	Nitzsch

<u>Pyrrophyta</u>

Ceratium hirundinella	(O.I. Muell) Dujardin
Glenodinium Borgei	(Lemm.) Schiller
Glenodinium species	(Ehrenberg) Stein
Peridinium gatunense	Nygaard
Peridinium cinctum	(Muell) Ehrenberg
Peridinium species	Ehrenberg
Peridinium pusillum	(Penard) Lemmermann

cont....

Chrysophyta

Dinobryon sertularia	Ehrenberg
Dinobryon calciformis	Bachmann
Dinobryon species	Ehrenberg
Cryptomonas erosa	Ehrenberg

Xanthophyta

Tribonenia species	Derbes & Solier
Tribonema affine	West, G.S.

Euglenophyta

Euglena species	Ehrenberg

Bacillariophyta

Iragilaria crotonensis	Kitton
Iragilaria capucina	Desm.
Iragilaria brevistrata	Grunow
Melosira granulata	(Ehr.) Ralfs
Melosira ambigua	(Grun.) Muller, O.
Cymbella affinis	Kuetzing
Amphiprora ornata	Bailey
Stephanodiscus astrea	(Ehr.) Grunow
Stephanodiscus magarae	Ehrenberg
Coscinodiscus rothii	(Ehr.) Grunow
Cocconeis pediculus	Ehrenberg
Cocconeis diminuta	Pantocsek
Tabellaria fenestrata	(Lyngb.) Kuetzing
Asterionella formosa	Hassal
Asterionella gravile	(Hantzsch) Heiberg
Mavicula peregrina	(Ehr.) Kuetzing
Cyclotella Meneghiniana	Kuetzing
Navicula pupula	Kuetzing
Cymatopheura solea	Pfuhlii Torka

TABLE VI

Comparisons between various methods of expressing phytoplankton biomass $cm^3.m^{-3}$, 10^{12} $ASU.m^{-3}$, chlor. a $mg.m^{-3}$. The significance level (P), experimental F value (F exp.), sample standard error ($S\bar{y}.x$), and number of observations (obs.) are included.

	P	F exp.	$S\bar{y}.x$	obs.
$10^{12}\ ASU.m^{-3} = 0.1844(10) - 0.5570(10^{-1})\ (cm^3.m^{-3}) + 0.6453(10^{-2})\ (Cm^3.m^{-3})^2$	0.005	291.22	0.2454	72
$cm^3.m^{-3} = 0.3931(10) + 0.1834(10)\ (10^{12}\ ASU.m^{-3})$	0.005	140.96	0.9673	72
Chlor. a $mg.m^{-3} = 0.5572(10) + 0.5392\ (cm^3.m^{-3})$	0.005	27.72	1.1084	62
Chlor. a $mg.m^{-3} = 0.5285(10) + 0.2050(10)\ (10^{12}\ ASU.m^{-3})$	0.005	19.29	1.1403	62

PHYSICAL CHARACTERISTICS

Transparency

Seasonal variations in the depth of the one percent isophot at each station during 1967, 1968, estimated from doubling the secchi disc reading, are illustrated in Figure 4. Maximum penetration of the trophogenic zone occurred at Conway in 1967 to a depth of 8 metres. Maximum depths at Glenora and Big Bay never exceeded 6 metres. Average and maximum depths of the one percent isophot are listed in Table VII as are the results of statistical comparisons between stations in which differences are significant at the $F_{.05}$ level.

Over the two year period the depth at which the one percent isophot occurred in Big Bay (BT) was significantly shallower than at Glenora (GT); at Glenora it was likewise definitely shallower than at Conway (CT). No differences are apparent between the same station in different years, nor between years for the Bay of Quinte overall (Quinte 7 = Quinte 8). Comparisons between the different stations in each year substantiate the trend indicated above - $B7 < G7 < C7$: $B8 < G8 < C8$.

Relationships between the transparency of water, of the depth of the one percent isophot (metres) and various measurements of the phytoplankton content were also investigated. At each location a linear relationship

Figure 4. Variations in depth of the one percent isophot (metres) at Big Bay, Glenora, and Conway in 1967, 1968.

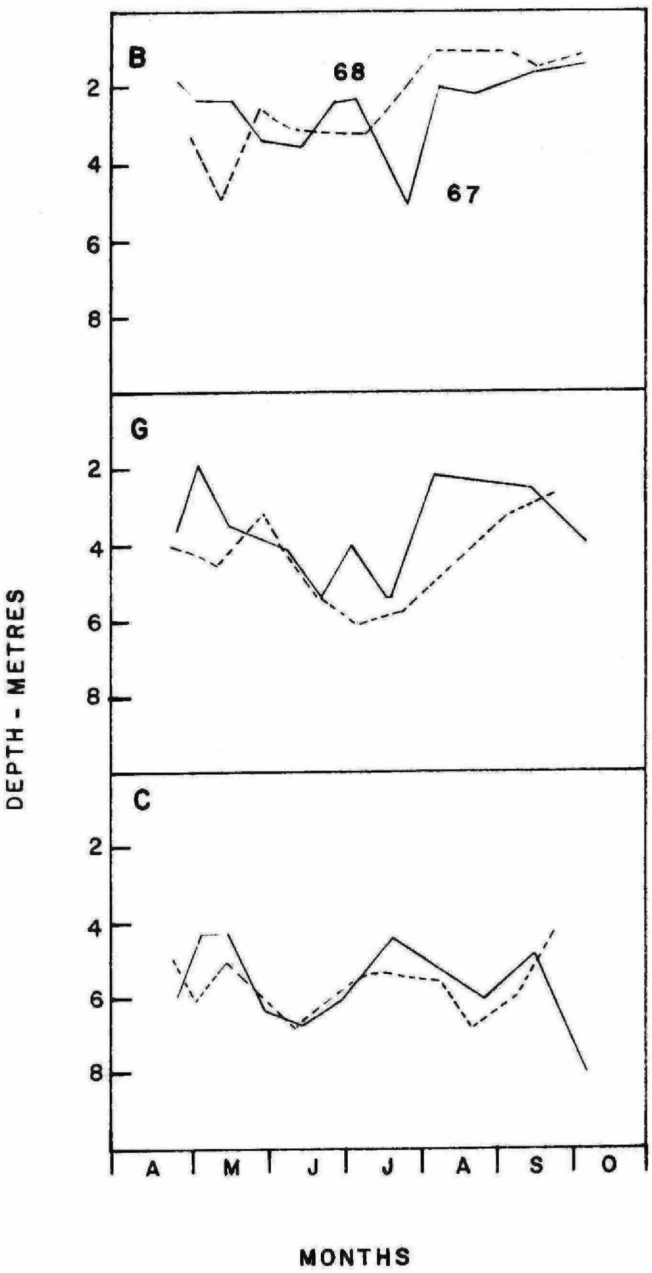


TABLE VII

Average and maximum depths of the one percent isophot (metres) and results of various comparisons significant at $F_{.05}$ level.

	1967			1968		
	$\bar{x}$	max.	obs.	$\bar{x}$	max.	obs.
Big Bay	2.6	3.60	12	2.3	4.8	12
Glenora	3.7	5.4	12	4.2	6.0	12
Conway	5.6	8.0	12	5.6	6.8	12

$$BT < GT < CT$$

$$B7 = B8; \quad G7 = G8; \quad C7 = C8$$

$$B7 < G7 < C7$$

$$B8 < G8 < C8$$

Quinte 7 = Quinte 8

was found to exist between the depth of the one percent isophot and at least one form of expression of the biomass (Table VIII). In two cases, however, the regression was for some reason positive, rather than negative.

Temperature

Temperature profiles were recorded at least monthly at Big Bay (one metre intervals), Glenora and Conway (two metre intervals) during 1967. During 1968 temperature observations were restricted to surface readings only.

Water temperature profiles from June to September, 1967 (Figure 5) demonstrate the achievement of a homothermal condition in Big Bay (B) by August. A depth constant cooling of the water column is evident in September. Temperature profiles at Glenora (G) depict the presence of complex stratification until a very deep homothermal penetration appeared in August. A uniform cooling of the water to a depth of about 12 metres is apparent in September. All temperature profiles at Conway (C) show varying degrees of complex stratification with the most stable regime occurring in August. In September the upper waters were found to be cooler than in August, but the temperature at depths greater than 18 metres was somewhat warmer.

TABLE VIII (cont)

	P	F	$S_{\bar{y}.x}$	obs.
Big Bay 1968				
1% (m) = 0.2821 (10) - 0.2820 (10^{-1}) ($cm^3.m^{-3}$)	0.05	5.12	0.3220	12
1% (m) = 0.2643 (10) - 0.4453 (10^{-1}) (10^{12} ASU.m^{-3})	0.10	3.50	0.3407	12
1% (m) = 0.3591 (10) - 0.6240 (10^{-1}) (mg chlor. a.m^{-3})	0.05	7.76	0.3338	9
Glenora 1968				
1% (m) versus $cm^3.m^{-3}$	<0.25	0.88		12
1% (m) versus (10^{12} ASU.m^{-3})	<0.25	0.01		12
1% (m) = 0.5676 (10) - 0.2387 (mg chlor. a.m^{-3})	0.10	3.45	0.1876	9
Conway 1968				
1% (m) = 0.5862 (10) - 0.1296 ($cm^3.m^{-3}$)	0.25	2.79	0.2242	12
1% (m) versus 10^{12} ASU.m^{-3}	<0.25	1.32		12
1% (m) versus mg chlor. a.m^{-3}	<0.25	0.03		9

TABLE VIII

Relationships between depth of the one percent isophot (metres) and phytoplankton density ($cm^3.m^{-3}$) (10^{12} $ASU.m^{-3}$) (chlor. a $mg.m^{-3}$) at Big Bay, Glenora, Conway, 1967, 1968, including significance level (P), experimental F value (F exp.), sample standard error ($S\bar{y}.x$) and number of observations (obs.).

	P	F	$S\bar{y}.x$	obs.
Big Bay 1967				
1% (m) = 0.3106 (10) - 0.3511 (10^{-1}) ($cm^3.m^{-3}$)	0.25	2.34	0.3032	12
1% (m) = 0.3969 (10) - 0.3887 (10^{12} $ASU.m^{-3}$)	0.10	4.33	0.2813	12
1% (m) = 0.3602 (10) - 0.5522 (10^{-1}) (mg chlor. a.m^{-3})	0.05	7.33	0.2686	11
Glenora 1967				
1% (m) versus $cm^3.m^{-3}$	$<$ 0.25	0.16		12
1% (m) versus 10^{12} $ASU.m^{-3}$	$<$ 0.25	0.04		12
1% (m) = 0.3144 (10) + 0.4595 (10^{-1}) (mg chlor. a.m^{-3})	0.25	1.82	0.3179	12
Conway 1967				
1% (m) versus $cm^3.m^{-3}$	$<$ 0.25	0.15		12
1% (m) = 0.3856 (10) + 0.1053 (10) (10^{12} $ASU.m^{-3}$)	0.25	2.37	0.3164	12
1% (m) versus mg chlor. a.m^{-3}	$<$ 0.25	1.26		12

cont....

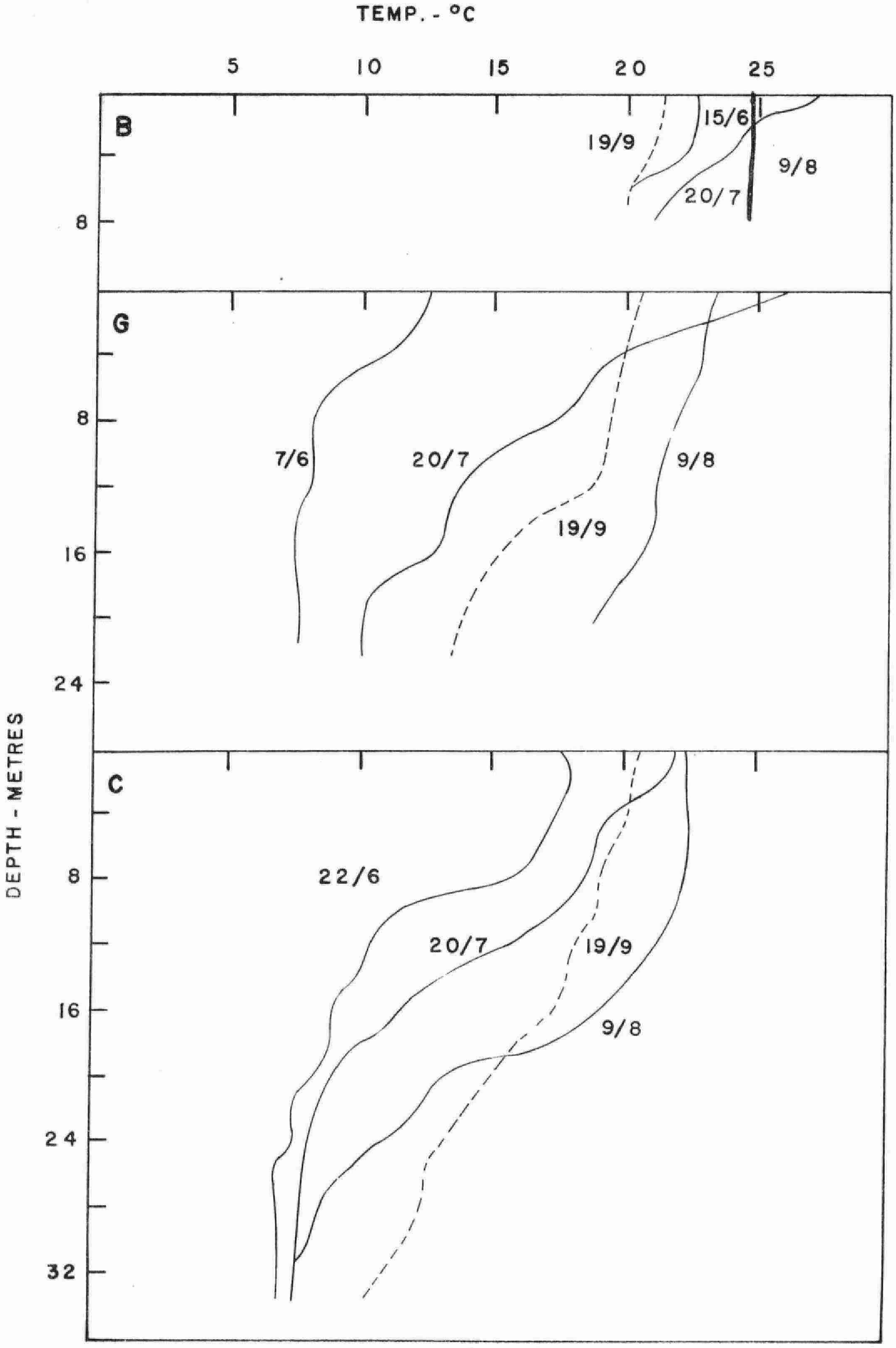


Figure 5. Temperature profiles (°C) during 1967 at Big Bay (B), Glenora (G) and Conway (C).

Seasonal changes in the temperature of the surface waters at each location during 1967 and 1968 are illustrated in Figure 6.

Dissolved Oxygen

Dissolved oxygen profiles were also recorded at least monthly during 1967 at each location. Observations in 1968 were restricted to examination of the bottom waters.

In Big Bay (B) (Figure 7), which had a vertical oxygen content of almost 90 percent saturation in May, a heterograde to clinograde oxygen profile became evident by late June. By July to September a very pronounced clinograde profile developed with supersaturated oxygen levels occurring in the surface waters.

The oxygen profile at Glenora in June displayed a more or less orthograde profile following by a trend toward a clinograde through July and August which became more pronounced by September.

At Conway (C) the profile in June is orthograde in appearance, shifting first to a positive heterograde form in June, a negative heterograde in August, and then becoming clinograde by September.

Seasonal changes in the dissolved oxygen content of the bottom waters at each location during 1967, 1968, including corresponding saturation values, are portrayed

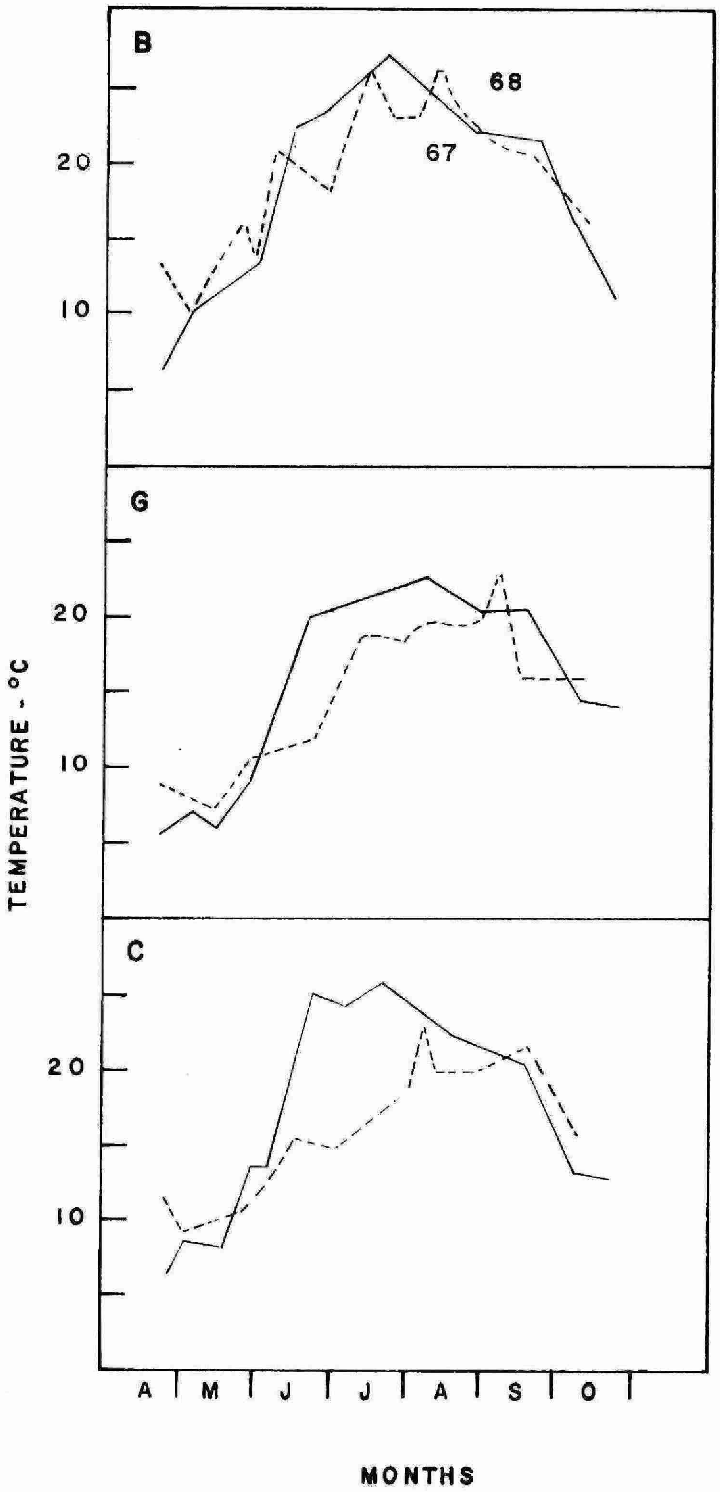


Figure 6. Surface water temperatures (°C) during 1967, 1968 at Big Bay (B), Glenora (G), and Conway (C).

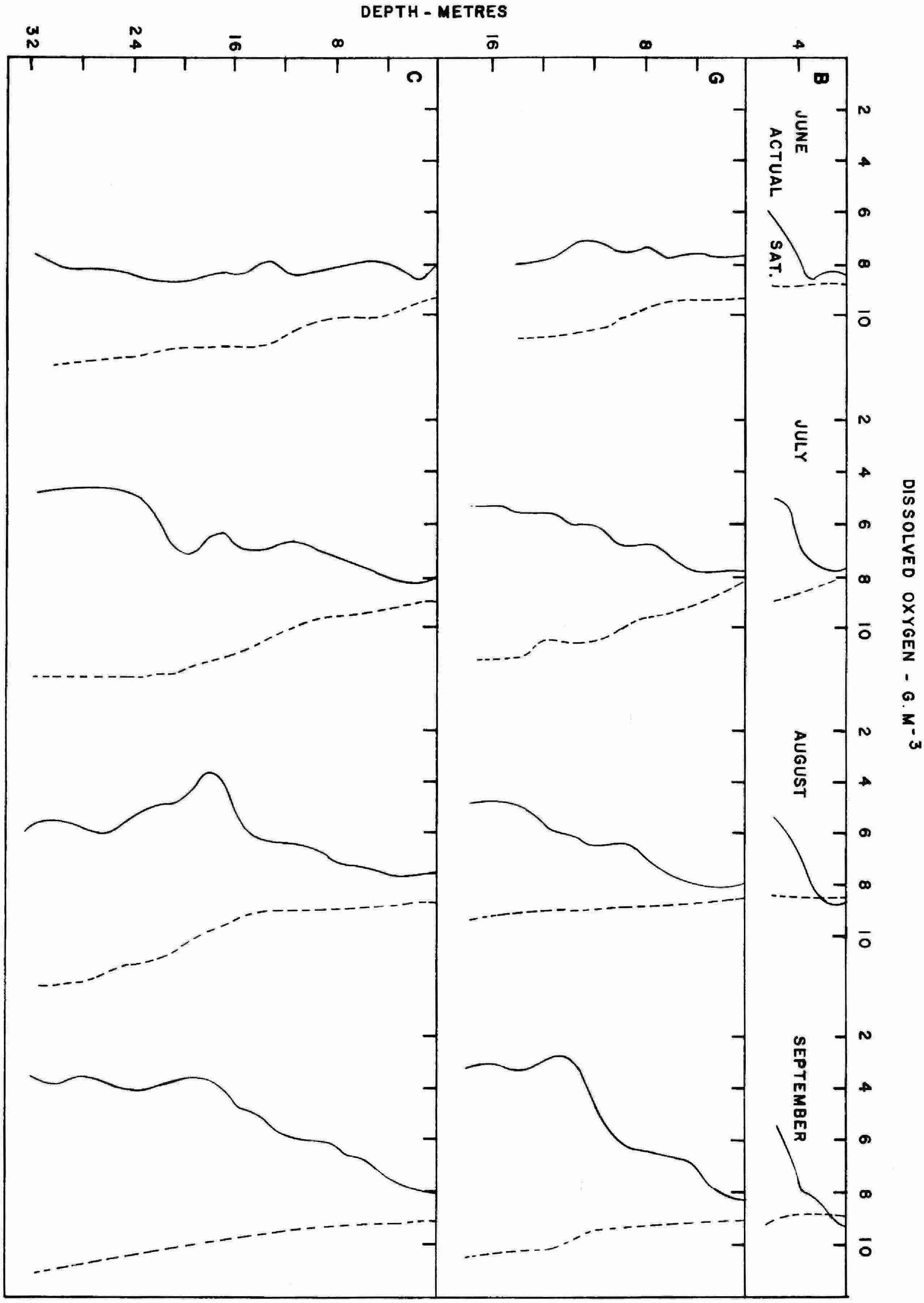


Figure 7. Dissolved oxygen profiles ($g.m^{-3}$) during 1967 at Big Bay (B), Glenora (G), and Conway (C). Profiles of 100 percent saturation are also shown.

in Figure 8. The loss of oxygen from these waters at each station in 1967 appears greater than in 1968. In Big Bay, 1968, four instances of supersaturation of the bottom waters were observed.

CHEMICAL CHARACTERISTICS

Major Ionic Composition

The major ionic composition of the trophogenic waters at Big Bay, Glenora, and Conway, including mean, minimum and maximum values, and the number of samples analyzed, is listed in Table IX. From data collected over the two year period comparisons between the three stations with respect to these parameters were tested statistically, differences being significant at the $F_{.05}$ level. The results of these analyses have been summarized below into four categories:

(1)	$B = G = C$	calcium, potassium, pH, alkalinity
(2)	$B < G < C$	sodium, chloride, conductivity, dissolved solids
(3)	$B < G = C$	magnesium, sulphate
(4)	$B > G = C$	total iron

Phosphorus, Nitrogen, Silicate

The phosphorus and nitrogen contents of the trophogenic waters at each station are summarized in Table X. Dissolved silicate data for the period April to July, 1968 have also been included. Results of comparisons

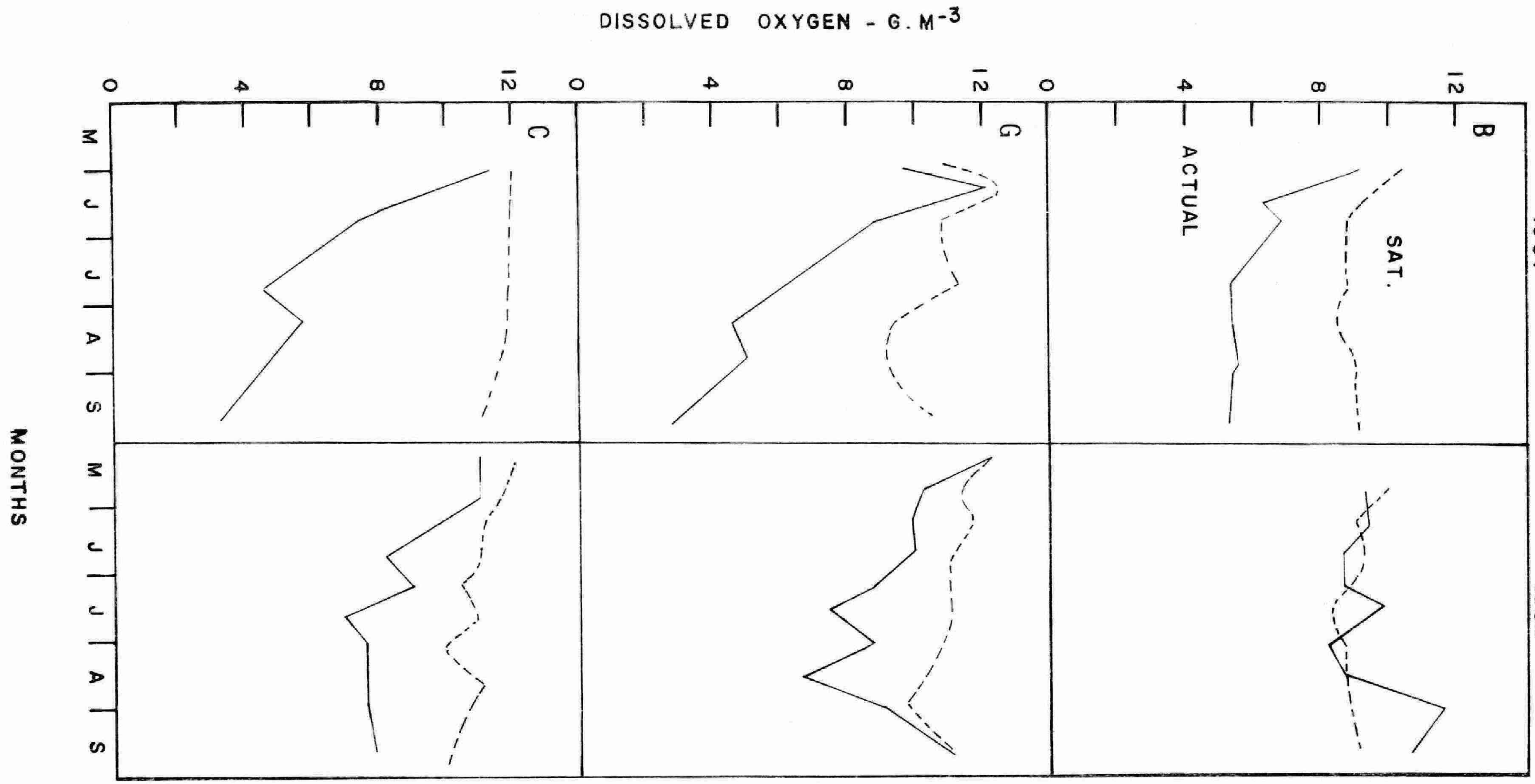


Figure 8. Dissolved oxygen content of bottom waters ($g.m^{-3}$) at Big Bay (B), Glenora (G) and Conway (C) during 1967, 1968, in comparison to 100 percent saturation content.

TABLE IX

Summary of the chemical characteristics of the trophogenic waters at Big Bay, Glenora, and Conway in 1967, 1968

		Big Bay				Glenora				Conway			
		mean	min.	max.	obs.	mean	min.	max.	obs.	mean	min.	max.	obs.
Calcium	$g.m^{-3}$	41	32	50	11	40	31	45	11	41	31	45	11
Magnesium	$g.m^{-3}$	4	3	6	11	6	2	9	11	6	4	8	11
Sodium	$g.m^{-3}$	4	3	5	8	7	3	11	8	9	4	12	8
Potassium	$g.m^{-3}$	1.2	1.0	1.5	10	1.2	1.1	1.5	10	1.3	1.2	1.6	10
Total Iron	$g.m^{-3}$	0.19	0.02	0.30	11	0.13	0.02	0.25	11	0.12	0.05	0.20	11
Sulphate	$g.m^{-3}$	18	10	22	9	24	16	30	10	25	21	29	9
Chloride	$g.m^{-3}$	5	4	6	9	15	4	24	9	19	8	26	9
Dissolved Solids	$g.m^{-3}$	161	102	212	21	176	129	230	21	190	128	226	21
Conductivity	$mho.cm^{-3}$	243	211	274	12	287	203	325	12	301	217	337	12
Alkalinity (as $CaCO_3$)	$g.m^{-3}$	103	92	119	21	100	94	109	21	99	93	116	21
pH		8.2	7.1	9.3	21	8.3	7.9	9.0	21	8.2	7.5	8.8	21

TABLE X

Summary of phosphorus, nitrogen and silicate characteristics of the trophogenic waters at Big Bay, Glenora, and Conway, 1967, 1968.

		Big Bay				Glenora				Conway			
		mean	min.	max.	obs.	mean	min.	max.	obs.	mean	min.	max.	obs.
<u>1967</u>													
Total Phosphorus	$g.m^{-3}$	0.062	0.020	0.103	12	0.039	0.017	0.067	12	0.038	0.020	0.067	12
Nitrate:N	$g.m^{-3}$	0.05	0.00	0.10	12	0.03	0.00	0.05	12	0.05	0.00	0.17	12
Nitrite:N	$g.m^{-3}$	0.002	0.000	0.010	12	0.002	0.000	0.011	12	0.003	0.000	0.012	12
Ammonia:N	$g.m^{-3}$	0.22	0.05	0.36	12	0.15	0.03	0.36	12	0.14	0.08	0.26	12
Inorganic N	$g.m^{-3}$	0.28	0.10	0.45	12	0.21	0.07	0.38	12	0.19	0.10	0.34	12
Organic N	$g.m^{-3}$	0.80	0.35	2.10	12	0.65	0.16	1.70	12	0.45	0.12	1.70	12
<u>1968</u>													
Total Phosphorus	$g.m^{-3}$	0.074	0.047	0.200	12	0.041	0.013	0.100	12	0.028	0.010	0.074	12
Nitrate:N	$g.m^{-3}$	0.02	0.01	0.04	12	0.06	0.01	0.14	12	0.03	0.01	0.37	12
Nitrite:N	$g.m^{-3}$	0.003	0.002	0.005	11	0.004	0.002	0.009	11	0.005	0.002	0.012	12
Ammonia:N	$g.m^{-3}$	0.30	0.01	0.10	12	0.14	0.08	0.48	12	0.10	0.03	0.21	12
Inorganic N	$g.m^{-3}$	0.19	0.05	1.12	12	0.26	0.02	0.48	12	0.18	0.02	0.59	12
Organic N	$g.m^{-3}$	0.62	0.25	0.94	12	0.41	0.08	0.75	12	0.30	0.05	0.48	12
Diss. Silicate	$g.m^{-3}$	0.72	0.11	2.40	8	0.87	0.27	3.80	8	1.59	0.25	5.10	8

with these data are indicated in Table XI, differences being significant at the $F_{.05}$ level.

The quantities of total phosphorus and inorganic nitrogen appear equivalent in the Bay of Quinte in 1967 and 1968, whereas the amount of organic nitrogen was greater in 1967. It is also evident that the quantities of phosphorus were consistently greater in Big Bay than at Glenora and Conway. Inorganic nitrogen levels were equivalent at all stations each year. Distribution of organic nitrogen throughout the Bay varies from year to year.

PHYTOPLANKTON:NUTRIENT RELATIONSHIPS

Fluctuations in the fertility of the trophogenic waters at each sampling location with respect to total phosphorus, nitrogen (total, organic, inorganic) and inorganic carbon (total, and CO_2) ($g.m^{-3}$) are illustrated in Figure 9 along with associated standing crops of phytoplankton ($cm^3.m^{-3}$).

Although several instances of phytoplankton development in relation to variations of these nutrients are apparent, the most dramatic response occurred in Big Bay, 1968 (B8) when an extremely large standing crop of phytoplankton (91 $cm^3.m^{-3}$) developed at a time when the concentrations of total phosphorus increased from about 0.050 to 0.200 $g.m^{-3}$. Phytoplankton:nutrient ratios at

TABLE XI

Comparisons with respect to concentrations of total phosphorus, inorganic nitrogen and organic nitrogen throughout the Bay of Quinte, 1967, 1968 ($g.m^{-3}$). Differences significant at $F_{.05}$ level.

Total Phosphorus	Inorganic Nitrogen	Organic Nitrogen
BT > GT = CT	BT = GT = CT	BT > GT = CT
B7 = B8; G7 = G8; C7 = C8	B7 = B8; G7 = C8; C7 = C8	B7 = B8; G7 > G8; C7 = C8
B7 > G7 = C7	B7 = G7 = C7	B7 = G7 > C7
B8 > G8 = C8	B8 = G8 = C8	B8 > G8 = C8
Quinte 7 = Quinte 8	Quinte 7 = Quinte 8	Quinte 7 = Quinte 8

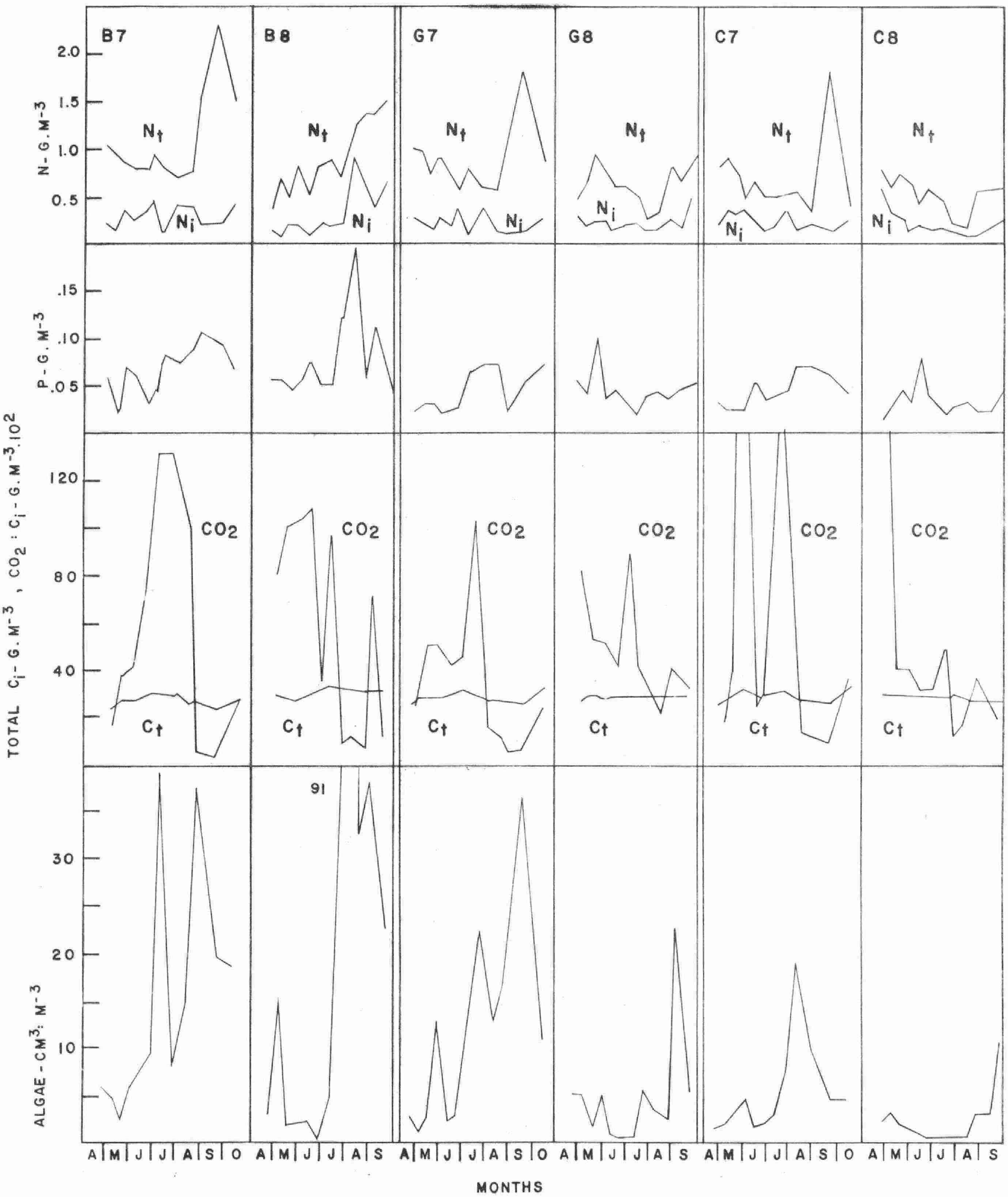


Figure 9. Concentrations of total phosphorus, total and inorganic nitrogen, total and CO_2 inorganic carbon ($g.m^{-3}$) and associated standing crops of algae ($cm^3.m^{-3}$) in the trophogenic waters at Big Bay (B), Glenora (G) and Conway (C) during 1967, 1968.

each station, or the average amount of phytoplankton per unit nutrient concentrations, for phosphorus and nitrogen, were calculated from the above data and are listed in Table XII. Maximum ratios for each station have also been included.

Regression testing between biomass quantities and nutrient concentrations were also carried out (Table XIII). Direct positive relationships between biomass and total phosphorus were found to exist at Big Bay (B7, B8), Glenora (G7) and Conway (C7). Other positive linear relationships are apparent such as between total nitrogen and biomass at B7, G7 and B8, and organic nitrogen and biomass at B7, G7 and B8. Although in 1967 inorganic nitrogen appears to decline directly with increasing biomass at B7, the opposite relationship was obtained with data of 1968 at the same location. At most stations no relationship is evident between biomass and total inorganic carbon excepting G8. Similarly no direct decline of carbon dioxide (CO_2) in association with increasing biomass was found except at B8.

Relationships between another nutritive material, dissolved silicate, and phytoplankton responses are illustrated for the period April through July, 1968 (Figure 10).

TABLE XII

Average and maximum ratios between phytoplankton quantities and total phosphorus, total nitrogen, and organic nitrogen concentrations at each sampling station during 1967, 1968 ($cm^3.m^{-3}:g.m^{-3}$).

	$cm^3:g\ P$			$cm^3:g\ N_T$			$cm^3:g\ N_O$		
	mean	max.	obs.	mean	max.	obs.	mean	max.	obs.
1967									
Big Bay	204:1	528:1	12	14:1	54:1	12	20:1	62:1	12
Glenora	332:1	1047:1	12	14:1	40:1	12	25:1	140:1	12
Conway	129:1	302:1	12	11:1	39:1	12	22:1	70:1	12
1968									
Big Bay	227:1	627:1	12	19:1	74:1	12	27:1	110:1	12
Glenora	125:1	562:1	12	10:1	29:1	12	18:1	75:1	12
Conway	109:1	397:1	12	5:1	21:1	12	8:1	31:1	12

TABLE XIII

Regression testing between phytoplankton densities ($cm^3.m^{-3}$) and total phosphorus (P), total, inorganic and organic nitrogen (N_T, N_i, N_o), total and CO_2 inorganic carbon (C_T, C_i) concentrations ($g.m^{-3}$) of the trophogenic waters at Big Bay, Glenora, Conway, in 1967, 1968. The significance level (P), experimental F value (F exp.), sample standard error ($S\bar{y}.x$) and number of observations (obs.) are included.

	P	F exp.	$S\bar{y}.x$	obs.
Big Bay 1967				
$cm^3.m^{-3} = -0.9707(10^{-3}) + 0.3866(10^{-5})\ (g\ P.m^{-3})$	0.01	10.18	2.94	12
$cm^3.m^{-3}$ versus $N_T\ g.m^{-3}$	$<$0.25	1.40		12
$cm^3.m^{-3}$ versus $C_T\ g.m^{-3}$	$<$0.25	0.45		10
$N_o\ g.m^{-3} = 0.5555(10^4) + 0.1660(10^3)\ (cm^3.m^{-3})$	0.25	2.11	0.1510	12
$N_i\ g.m^{-3} = 0.3326(10^4) - 0.3682(10^2)\ (cm^3.m^{-3})$	0.25	2.08	0.0337	12
$C_i\ g.m^{-3}$ versus $cm^3.m^{-3}$	$<$0.25	0.05		10
Glenora 1967				
$cm^3.m^{-3} = 0.3060(10^{-3}) + 0.2192(10^{-5})\ (P\ g.m^{-3})$	0.25	2.45	3.01	12
$cm^3.m^{-3} = -0.4894(10^{-3}) + 0.1920(10^{-6})\ (N_T\ g.m^{-3})$	0.05	6.34	2.63	12
$cm^3.m^{-3}$ versus $C_T\ g.m^{-3}$	$<$0.25	0.52		10
$N_o\ g.m^{-3} = 0.4003(10^4) + 0.2172(10^3)\ (cm^3.m^{-3})$	0.05	5.04	0.1028	12
$N_i\ g.m^{-3}$ versus $cm^3.m^{-3}$	$<$0.25	0.33		12
$C_i\ g.m^{-3}$ versus $cm^3.m^{-3}$	$<$0.25	0.01		10

cont....

TABLE XIII (cont)

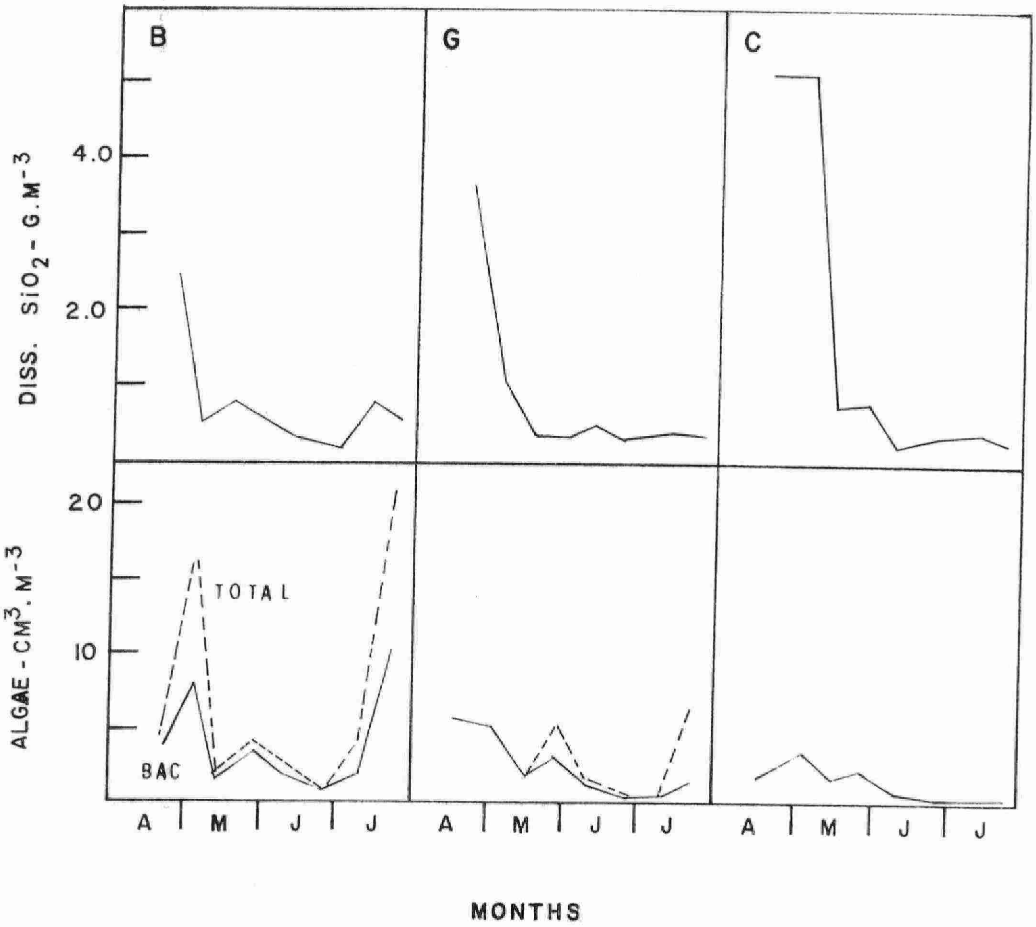
	P	F exp.	$S\bar{y}.x$	obs.
Conway 1967				
$cm^3.m^{-3} = -0.3371(10^{-3}) + 0.2257(10^{-5})$ $(P\ g.M^{-3})$	0.01	9.62	1.201	12
$cm^3.m^{-3}$ versus $N_T\ g.m^{-3}$	<0.25	0.39		12
$cm^3.m^{-3}$ versus $C_T\ g.m^{-3}$	<0.25	0.17		11
$N_o\ g.m^{-3}$ versus $cm^3.m^{-3}$	<0.25	0.15		12
$N_i\ g.m^{-3}$ versus $cm^3.m^{-3}$	<0.25	0.97		12
$C_i\ g.m^{-3}$ versus $cm^3.m^{-3}$	<0.25	0.08		11
Big Bay 1968				
$cm^3.m^{-3} = 0.1590(10^{-2}) + 0.4816(10^{-5})$ $(P\ g.m^{-3})$	0.005	33.06	3.94	12
$cm^3.m^{-3} = 0.1826(10^{-2}) + 0.4310(10^{-6})$ $(N_T\ g.m^{-3})$	0.05	6.15	6.43	12
$cm^3.m^{-3}$ versus $C_T\ g.m^{-3}$	<0.25	1.16		11
$N_o\ g.m^{-3} = 0.5299(10^4) + 0.4727(10^2)$ $(cm^3.m^{-3})$	0.05	5.43	0.0524	12
$N_i\ g.m^{-3} = 0.9856(10^3) + 0.1110(10^2)$ $(cm^3.m^{-3})$	0.005	44.71	0.0429	12
$C_i\ g.m^{-3} = 0.7885 - 0.9260(10^{-2})$ $(cm^3.m^{-3})$	0.05	7.27	0.115	11

cont....

TABLE XIII (cont)

	P	F exp.	$S\bar{y}.x$	obs.
Glenora 1968				
$cm^3.m^{-3}$ versus P $g.m^{-3}$	<0.25	0.00		12
$cm^3.m^{-3}$ versus N_T $g.m^{-3}$	<0.25	0.00		12
$cm^3.m^{-3} = 0.7186(10^2) - 0.2405(10)\ (C_T\ g.m^{-3})$	0.10	3.98		10
N_o $g.m^{-3}$ versus $cm^3.m^{-3}$	<0.25	0.00		12
N_i $g.m^{-3}$ versus $cm^3.m^{-3}$	<0.25	0.00		12
C_i $g.m^{-3}$ versus $cm^3.m^{-3}$	<0.25	0.02		10
Conway 1968				
$cm^3.m^{-3}$ versus P $g.m^{-3}$	<0.25	0.18		12
$cm^3.m^{-3}$ versus N_T $g.m^{-3}$	<0.25	0.79		12
$cm^3.m^{-3}$ versus C_T $g.m^{-3}$	<0.25	0.63		10
N_o $g.m^{-3}$ versus $cm^3.m^{-3}$	<0.25	0.62		12
N_i $g.m^{-3}$ versus $cm^3.m^{-3}$	<0.25	0.10		12
C_i $g.m^{-3}$ versus $cm^3.m^{-3}$	<0.25	0.02		10

Figure 10. Fluctuations of dissolved silicate ($g.m^{-3}$) and of total and diatom standing crops at Big Bay (B), Glenora (G), and Conway (C), April through July, 1968.



Comparisons between stations with respect to silicate levels and diatom production, from the above, were carried out (Table XIV): in the former B = G = C, whereas in the latter B = G, B$>$C, G = C. Regression testing between the two parameters indicates significant positive relationships to exist at Glenora and Conway but not at Big Bay. The possible influence of silicate availability as a regulator of phytoplankton response would appear to subsequently decline with a shift in community domination to the Cyanophyta in July, particularly at Big Bay and Glenora (Figure 10).

DISCUSSION

Phytoplankton communities of the inner and outer regions of the Bay of Quinte do not appear to have altered qualitatively when compared to earlier observations of Tucker (1948) and McCombie (1967), the inner region being dominated by the Cyanophyta and the outer by the Bacillariophyta (Table IV, Figure 3). Other forms account for only about ten percent of the population.

According to McCombie (1967), the inner region, with an average phytoplankton concentration of 3.523 X 10^{12} ASU.m^{-3}, produced about ten times more than the middle region and 100 times more than the outer region. Average quantities during 1967-1968 have almost doubled in Big Bay, 6.46 X 10^{12} ASU.m^{-3}, tripled at Glenora and

TABLE XIV

Dissolved SiO_2 (g. $^{-3}$) and diatom concentrations ($cm^3.m^{-3}$): A) Comparison between stations - differences significant at $F_{.05}$. B) Regression relationships - significance level (P), experimental F value (F), sample standard error ($S\bar{y}.x$), number of observations (obs.).

A)

	B	G	C	
dissolved SiO_2	0.72	0.87	1.59	B = G = C
diatoms	3.70	2.54	1.16	B = G; B > C; G = C

B)

	P	F exp.	$S\bar{y}.x$	obs.
Big Bay				
$cm^3.m^{-3}$ versus g $SiO_2.m^{-3}$	< 0.25	0.00		8
Glenora				
$cm^3.m^{-3} = 0.1166(10) + 0.1293(10)$ (g $SiO_2.m^{-3}$)	0.05	7.63	0.569	8
Conway				
$cm^3.m^{-3} = 0.5264 + 0.4093$ (g $SiO_2.m^{-3}$)	0.05	8.90	0.299	8

increased more than tenfold at Conway (Table II), so that the amount which developed in Big Bay was only three times greater than that observed from the outer region at Conway.

Tentative criteria have been suggested for classifying the trophic status of surface waters based on maximum standing crops of phytoplankton expressed as parts per million by volume ($cm^3.m^{-3}$) and chlorophyll a concentrations ($mg.m^{-3}$) (Vollenweider, 1970).

	$cm^3.m^{-3}$		chlorophyll a $mg.m^{-3}$
ultraoligotrophic	< 1	oligotrophic	0.3 - 2.5
meso to eutrophic	3 - 5	mesotrophic	1 - 15
highly eutrophic	> 10	eutrophic	5 - 140

Maximum standing crops associated with the three sampling locations each year per unit volume (m^{-3}): B7 - 40.72 cm^3, 45.2 mg chlor. a; G7 - 37.43 cm^3, 30.6 mg chlor. a; C7 - 20.25 cm^3, 12.8 mg chlor. a; B8 - 91.00 cm^3, 51.59 mg chlor. a; G8 - 22.49 cm^3, 10.2 mg chlor. a; C8 - 10.73 cm^3, 6.09 mg chlor. a - indicate that all locations should be classified as eutrophic to highly eutrophic (Table II).

While phytoplankton development throughout the Bay of Quinte was found comparable in 1967 and 1968 the distribution of algal quantities within the Bay differed each year (B7 = G7 = C7: B8 $>$ G8 = C8) (Table III).

The fact that the lowest quantity produced at any station, Conway, 1968 (C8) occurred at the same time as the highest quantity developed in Big Bay, suggests that biomass development in the outer region may be closely related to the extent of nutrient utilization in the inner zone.

Of the various nutritive materials contributing to biomass development, attention has been focused primarily on relationships involving phosphorus, nitrogen, inorganic carbon and to a lesser extent, silicate. With respect to phosphorus quantities, the amount present throughout the Bay of Quinte was found equivalent between years (Q7 = Q8) (Table XI) with distribution within the system at the three locations being comparable each year (B7 > G7 = C7:B8 > G8 = C8), unlike that of the phytoplankton biomass (Table III). It has been further demonstrated that a positive direct relationship exists between the biomass and total phosphorus levels at four time locations - B7, G7, C7, B8 (Table XIII). Phosphorus would not, however, appear to be limiting phytoplankton responses at G8 or C8.

Quantities of inorganic nitrogen throughout the Bay were similarly found to be equivalent between years (Q7 = Q8) and between stations each year (B7 = G7 = C7: B8 = G8 = C8) (Table XI). The only example of a negative direct relationship between inorganic nitrogen and increasing biomass occurred at Big Bay, 1967 (B7) (Table XIII),

therefore while nitrogen availability was perhaps limiting algal responses in this region, it would not appear to be exerting the same influence elsewhere. In fact a positive direct relationship was found to exist between inorganic nitrogen and biomass in Big Bay, 1968 (B8) (Table XIII).

The amounts of organic nitrogen in the trophogenic waters of the Bay of Quinte were found to be significantly greater in 1967 than in 1968 and did not follow a distribution pattern within the Bay in 1967 (B7 = G7 $>$ C7) (Table XI) as noted with the biomass, although a similar pattern did occur in 1968 (B8 $>$ G8 = C8). A direct positive relationship between organic nitrogen levels and biomass is evident however only at two locations - B7, G7 (Table XIII).

According to King (1970), carbon dioxide concentrations between 0.120 - 0.030 g carbon.m^{-3} tend to favour the development of certain Cyanophyta rather than Chlorophyta, which cannot tolerate concentrations below 0.120 g carbon.m^{-3}. During 1967, carbon dioxide concentrations, as calculated from pH and calcium carbonate alkalinity data (after Ruttner 1963), within this range occurred at the three locations as well as in Big Bay, 1968 (Figure 9) but did not decrease below 0.120 g carbon.m^{-3} at Glenora or Conway in 1968. A negative direct relationship between CO_2 carbon and increasing biomass was found only with data from Big Bay, 1968, when standing crops assumed concentrations more typically associated with waste stabilization

From comparisons between stations carried out with other chemical moieties, only total iron levels, as with phytoplankton quantities (Table III) were found to be significantly greater in Big Bay than at Glenora or Conway. Comparison of these data with the results of previous studies carried out in several Kawartha lakes (Christie, 1968), where standing crops of algae ($1.91 - 2.44 \times 10^{12}$ ASU.m^{-3}) are approximately equivalent to the average quantities at Glenora and Conway (1.31 and 2.12×10^{12} ASU.m^{-3}) although the total iron levels are less, 0.04 - 0.09 g.m^{-3} versus 0.14 and 0.15 g.m^{-3}, would imply that iron is not restricting phytoplankton developments at these two locations.

Restrictions on phytoplankton growth related to limitations imposed by the availability of other nutritive materials, such as dissolved silicate, would be expected to influence any estimate of the average efficiencies of biomass production as related to phosphorus or nitrogen such as were calculated (Table XIII). The most meaningful ratios observed in this study may be therefore the maximum biomass nutrient relationships which were obtained with each parameter - 1047 cm^3/g phosphorus, 73 cm^3/g total nitrogen, 307 cm^3/g organic nitrogen. Inversion of these ratios then suggests that 1 cm^3 of phytoplankton may be produced in the presence of 0.00095 g.m^{-3} total phosphorus, 0.0133 g.m^{-3} total nitrogen or 0.00325 g.m^{-3} organic nitrogen.

ponds. Whether the low levels of carbon dioxide contributed indirectly to, or resulted from, excessive growths of blue-green algae, however, requires further study. Evidently, however, the development of maximum standing crops in excess of 10 $cm^3.m^{-3}$ can occur, as noted at Glenora and Conway, 1968, without carbon dioxide availability being reduced below 0.120 g $carbon.m^{-3}$.

Lund et al (1963) suggest that dissolved silicate concentrations of 0.4 - 0.5 $g.m^{-3}$ or less may exert a limiting effect on diatom development. During the spring and early summer, 1968, the dissolved silicate levels at each station were observed to be less than the above values by June (Figure 10). However, significant direct relationships between dissolved silicate levels and diatom biomass were only found to exist at Glenora and Conway but not in Big Bay. Although the amounts of dissolved silicate remaining in the water were comparable between stations, the diatom biomass generated at Big Bay was significantly greater than at the other two locations (B8 $>$ G8 = C8) (Table XIV) over this period. Silicate availability is therefore probably a limiting factor at Glenora and Conway. In view of the above, it would be interesting to know just how quickly silicate was being regenerated in a shallow water environ, thus contributing to the significantly greater amount of diatoms which developed in Big Bay, even though apparent dissolved silicate levels are comparable at all stations.

Although the phosphorus value may appear quite low, it is still in excess of the amount required in the production of 1 $cm^3.m^{-3}$ of such algal forms as <u>Microcystis</u>, <u>Oscillatoria</u>, <u>Fragilaria</u>, which range from 0.0002 - 0.0006 $g.m^{-3}$ (Vollenweider, 1970).

As pointed out above, the suggested breakpoint between a meso and eutrophic surface water is 3 - 5 $cm^3.m^{-3}$ on the basis of maximum phytoplankton concentrations. The maximum concentrations for total phosphorus and total nitrogen in the trophogenic zone should therefore be in the order of 0.003 = 0.005 $g.m^{-3}$ total phosphorus and 0.04 - 0.07 $g.m^{-3}$ total nitrogen. Phytoplankton concentrations in excess of 10 $cm^3.m^{-3}$, which could be considered a bloom, would therefore be expected to occur when total phosphorus and total nitrogen levels are allowed to exceed and remain in excess of 0.01 $g.m^{-3}$ and 0.13 $g.m^{-3}$ respectively, if no other factor is exerting a restrictive influence on phytoplankton development.

SUMMARY

1) The Bay of Quinte, on the basis of maximum standing crops of phytoplankton represents a eutrophic to hypertrophic situation.

2) Direct relationships were obtained between phytoplankton quantities and levels of phosphorus, nitrogen, inorganic carbon and dissolved silicate.

3) Concentrations of total phosphorus and total nitrogen allowed to exceed and remain in excess of 0.01 mg/l and 0.13 mg/l, respectively, are projected to have a theoretical capability of producing nuisance levels of phytoplankton.

REFERENCES

American Public Health Assoc. 1965, Standard methods for the examination of water and wastewater. 12th ed., 769 p.

Birge, E.A. and Juday, C., 1922, The inland lakes of Wisconsin, The plankton I. Its quantity and chemical composition. Bull. Wis. Geol. Nat. Hist. Surv. 64 (Sci. ser. 13), 222 p.

Brydges, T.G., 1970, Outlines of analytical methods. Div. of Laboratories, OWRC.

Chapman, L.J. and Putnam, D.F., 1962, The physiography of southern Ontario. Univ. Toronto Press, 2nd ed. Toronto, 386 p.

Christie, A.E., 1968, Nutrient-phytoplankton relationships of eight southern Ontario lakes. OWRC Research Pub. No. 32, 37 p.

Frere Irene Marie, 1938, Flore Desmidiale de la Region de Montreal. J.C. Chaumont, Laprairie, Canada, 547 p.

Johnson, M.G., Michalski, M.F.P. and Christie, A.E., 1970, Effects of acid mine wastes on phytoplankton communities of two northern Ontario lakes. J. Fish. Res. Bd. Canada, 27:425-444.

King, D.L., 1970, The role of carbon in eutrophication. J. Water Poll. Cont. Fed., 42:2035-2051

Lund, J.W.G., Mackerath, F.J.H. and Mortimer, C.H., 1963, Changes in depth and time of certain chemical and physical conditions and of the standing crop of Asterionella formosa Haas in the North Basin of Windermere in 1947. Phil. Trans. Ray. Soc., 246 B:225-290.

McCombie, A.M., 1967, A recent study of the phytoplankton of the Bay of Quinte 1963-1964. Proc. Tenth Conf. Gt. Lakes Res., Internat. Assoc. Gt. Lakes Res., 37-42.

Prescott, G.W., 1962, Algae of the Western Great Lakes area. W.C. Brown Co., Dubuque, Iowa, 2nd ed., 977 p.

Ruttner, F., 1963, Fundamentals of limnology. Trans. D.G. Frey and F.E. Fry, U. of Toronto Press, 3rd ed., 295 p.

Sieminska, J., 1964, Bacillariophyceae Okrzemki. Polska Akad. Nauk. Inst. Bot., Panstwowe Wydawnictwo Naukowe, Warszawa, 610 p.

Smith, G.M., 1950, Fresh-water algae of the United States. McGraw-Hill Book Co., New York, 719 p.

Snedecor, G.W. and Cochran, W.G., 1956, Statistical methods applied to experiments in agriculture and biology. Iowa State College Press, Ames, Iowa, 5th ed., 534 p.

Tucker, A., 1948, The phytoplankton of the Bay of Quinte. Trans. Am. Microscop. Soc., 47:365-383.

Vollenweider, R. A., 1970, Scientific fundamentals of the eutrophication of lakes and rivers, with particular reference to nitrogen and phosphorus as factors in eutrophication. Organization for Economic co-operation and Development, Paris, France, 159 p.

- NOTICE -

This report is made in good faith and from information believed to be correct, but without any guarantee of any kind whatsoever, whether express or implied, with respect thereto, and in particular, the Ministry disclaims any responsibility for the accuracy, completeness or usefulness of the report and does not represent or warrant that the use of the information contained in the report will conform to the law or may not infringe any rights under the law.

The Ministry and its employees and agents shall not be liable in any manner whatsoever in respect of the information contained in the report, and any use of such information shall be at the risk of the user.

96936000009322